Assessment of the Talk Test and Rating of Perceived Exertion for Exercise Intensity Prescription in Persons With Paraplegia

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Background: Physical activity recommendations require accurate estimations of exercise intensity. Rating of Perceived Exertion (RPE) and talk test (TT) are 2 commonly recommended techniques to gauge intensity. It is not known whether these are valid to select an exercise intensity that would elicit a training effect for persons with spinal cord injury (SCI). **Objective:** To define the exercise intensity of each TT stage and RPE exercise intensity category and assess whether persons with paraplegia are able to use the TT to select a "comfortable" exercise workload they could maintain for 15 minutes. **Methods:** Twelve participants with paraplegia completed 2 arm crank exercise tests on nonconsecutive days within 14 days. Test 1 was an incremental peak effort assessment. Test 2 was a 15-minute simulated exercise session at a participant-selected fixed workload. During each test, participants reported their RPE and performed a TT at 2-minute intervals. **Results:** The intensity of the first negative TT stage was vigorous (75 ± 15 %VO_{2R}); at low and moderate intensities, perceived effort was greater than measured intensity; at vigorous and maximal intensities, perceived effort matched measured intensity. Individuals successfully used the TT to select an exercise workload they could maintain for 15 minutes. RPE, but not exercise intensity, increased during the 15-minute session. **Conclusions:** During arm crank exercise when speaking is not comfortable (ie, first negative TT), persons with paraplegia are exercising at vigorous intensity, which is sufficient to elicit training effects. During incremental peak exercise testing, RPE does not appear to accurately index low-moderate exercise intensities. During the simulated exercise session, RPE appeared to index peripheral fatigue. **Key words:** *exercise, perceived exertion, spinal cord injury, talk test*

Daily exercise and physical activity (PA) are recognized as foundations of health, wellness, and physical independence across the lifespan for all individuals. PA recommendations issued in 2008 by the US Department of Health and Human Services (US HHS) emphasize that the target minimum weekly PA level for adults with and without disabilities is the same.[1] This recommendation recognizes that a disability may physically limit the amount of activity a person can achieve, but emphasizes that, even for persons with disabilities, PA is important, some activity is better than none, and sedentary behavior should be avoided. Although activity recommendations for persons with and without disability may be similar, the population-specific exercise prescription may differ.[2] Nevertheless, all aerobic exercise recommendations[1-3] include 4 components: (1) number of sessions per week; (2) session duration (minutes); (3) session intensity (moderate or vigorous); and (4) session activity options (mode). Typically, multiple sessions per week are recommended, and any activity achieving the target intensity is acceptable. As a general rule, an inverse relationship exists between session intensity and session duration. Health and fitness benefits are achieved by fewer minutes at vigorous intensities. Conversely, moderate intensities require longer durations to achieve the target benefits. Thus, if people with SCI are to improve their health and wellness through PA, they must be able to accurately assess their exercise intensity.

Two popular "field" approaches to assessing exercise intensity include the rating of perceived exertion (RPE) and the talk test (TT). RPE is a somatic rating of effort and is commonly assessed with the 6-20 point (categorical) scale of Borg. In the general population, the Borg RPE is a direct representation of exercise heart rate response (HRR). However, this relationship may not hold true in the SCI population.[4] Despite this limitation, RPE reported by persons with SCI increases as a function of workload,[4] an indication that it tracks exercise intensity albeit absent a solid relationship with heart rate. Additional work indicates that

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Table 1. Individual participant demographics

	Injury level	Gender	Age, years	Weight, kg	Height, cm	Duration of injury, years
	T3	M	26	78.9	170.2	16
	T3	F	26	62.1	170.2	26
	T4	M	20	70.3	167.6	4
	T6	M	21	90.7	170.2	2
	T6	M	29	102.1	188.0	11
	T6	M	44	68.0	188.0	22
	T7	F	23	62.1	162.6	4
	T9	M	32	84.8	182.9	14
	T10	M	33	97.5	190.5	11
	T12	F	27	45.4	170.2	15
	T12	M	32	63.5	182.9	15
	L1	M	32	72.8	170.2	14
Average	-	9M/3F	28.8	74.8	176.1	12.8
SD	-	-	6.5	16.6	9.6	7.3

highly fit persons with SCI are able to use RPE to maintain a self-selected exercise intensity.[5]

The TT, an assessment of speaking comfort during exercise, is another option for self-estimation of exercise intensity. It is grounded in studies demonstrating concurrence between the point when sustained speech becomes difficult during exercise and the exercise ventilatory threshold (VT). The VT describes the nonproportional increase in carbon dioxide production relative to oxygen consumption, and it is temporally associated with the lactate threshold.[6] The VT typically occurs at moderate intensity work in nondisabled, untrained individuals (50%-60% peak oxygen consumption [$\%VO_{2peak}$]),[7,8] at vigorous intensity in nondisabled aerobically trained individuals (60%-80% VO_{2peak}),[7,9] and at vigorous intensity (68%-70% VO_{2peak}) in a mixed cohort of persons with paraplegia or lower extremity amputations.[10] To our knowledge, the TT has not been evaluated as a method to select exercise intensity in the SCI population.

Although RPE has been successfully used by persons with SCI to regulate their prescriptive exercise intensities,[5] we are unaware of attempts to establish exercise intensities of RPE typically cited as representing moderate and vigorous effort. Additionally, because discomfort during speaking is linked to the exercise VT, which occurs at moderate to vigorous intensities, the TT may be a valid technique for persons with SCI to select an exercise intensity that would elicit a training effect. However, this has not yet been established. Therefore, our objectives were to (1) define the exercise intensity of the TT stages and perceived effort intensity categories; (2) assess whether persons with SCI are able to use the TT to select a comfortable workload that they can sustain for a 15-minute simulated exercise session; and (3) determine if the intensity of the selected workload was comparable between the peak test and simulated exercise session.

Methods and Materials

Participants

Twelve young adults (9 men, 3 women; 29 ± 7 years old) who were recruited from the Miami Project to Cure Paralysis subject database completed the study (**Table 1**). All participants had an SCI at T1 or lower (injury level self-reported), were at least 1 year post injury, were asymptomatic for acute treatable illness or infection, did not have a history of known cardiovascular disease, did not experience any back or shoulder pain that limited exercise, and had never been told by a physician not to exercise. Additionally, all participants self-

reported a complete injury and an inability to move their lower extremities. The institutional review board approved the study. Before participating, the individuals were advised of the risks of research and provided written informed consent.

Exercise test protocols

Participants completed 2 exercise tests on nonconsecutive days within a 14-day period using a calibrated, electronically braked ergometer (Lode Angio V2, Type 917900; Lode BV, Groningen, The Netherlands). Test 1 (T_{peak}) was a multistage continuous graded peak arm crank ergometer assessment. Following a 10-minute quiet rest period to establish baseline oxygen consumption via open circuit spirometry (Vmax 2130 System, SensorMedics Model 922 Spirometer; SensorMedics Corporation, Yorba Linda, California), the test began at 0 W and increased by 10 W every 2 minutes until test termination.[11] Using a digital real-time display, subjects maintained a cranking cadence between 55 and 65 rpm for both tests. Both tests were terminated at volitional fatigue and were followed by a 5-minute passive recovery period. Test 2 (T_{15min}) was a 15-minute single stage exercise session. Each participant chose a workload they felt they could comfortably maintain for 15 minutes based on their TT results from T_{peak}. It was also preceded by a 10-minute quiet rest and followed by a 5-minute passive recovery.

Breath-by-breath oxygen consumption (VO_2, L/min^{-1}) for both tests was continuously measured via open circuit spirometry during baseline rest, exercise, and recovery. Average VO_2 was generated for each consecutive 30 second period (0-30 seconds, 30-60 seconds, 60-90 seconds, etc). Baseline VO_2, defined as the lowest baseline 30 second average, was recorded for each test. Peak VO_2 (VO_{2peak}) was defined as the highest 30 second average recorded during test one (T_{1peak}).The VO_2 for every 2-minute stage or period (VO_{2stage}) of each test was defined as the 30 second average occurring immediately prior to each administration of the TT, corresponding to the 60-90 second period of each stage. This period was selected to avoid the artificial elevation of VO_2 induced by speaking.

TT and RPE administration

During the last 30 seconds of each 2-minute stage (T_{peak1}) or period (T_{15min}), RPE was documented and the TT was administered. First, participants reported their perceived effort using Borg's 6-20 categorical RPE scale. Then participants recited a standardized 31-word passage (TT). Immediately upon completing the passage, participants were asked, "Can you still speak comfortably?" A response of "yes" was coded as a positive TT and "no" as negative. If the subject equivocated in any way, the TT was coded equivocal. Four TT stages of interest have been previously identified[11,12]; first negative, equivocal, the last positive stage, and the stage before the last positive (last positive -1).

Data reduction and analysis

The exercise intensity for each stage (or period) was operationally defined as percent VO_2 reserve ($\%VO_{2R}$), defined as the difference between VO_{2peak} and resting VO_2 (VO_{2peak} - VO_{2rest}).

Resting VO_2 was operationalized as the average pre-exercise baseline VO_2 of the 2 tests. Percent VO_{2R} was computed as follows:

$$((VO_{2stage} - VO_{2rest})/VO_{2R})*100$$

Outcome variables

Five time points of the peak test were identified for analysis: VO_{2peak}, first negative, equivocal, last positive, and last positive -1. For each of these points, 2 variables were recorded for analysis: percentage of peak oxygen consumption reserve ($\%VO_{2R}$), and RPE. Two additional variables were generated by coding the exercise intensity of $\%VO_{2R}$ (light, <40%; moderate, 40%-59%; vigorous, 60%-84%; maximal, ≥85%) and RPE (light, 6-11; moderate, 12-14; vigorous, 15-17, maximal, 18-20).[13]

For the 15-minute single stage exercise session, 2 points were identified for analysis: the incremental test stage selected by the participant as their 15-minute steady state workload and the average of the final 10 minutes of the steady state test. For each of these points, peak oxygen consumption reserve ($\%VO_{2R}$) and RPE were recorded and the intensity classifications for both were generated

for analysis. In addition, the selected workload was documented.

Data analyses

To define the actual intensity of the 4 TT stages and 4 RPE intensity categories, we used the incremental exercise test data and computed mean $\%VO_{2R}$ and 95% confidence interval of the mean (95% CI) of each TT stage or RPE category. To assess if persons with SCI are able to use the TT to select a comfortable exercise intensity that they could sustain for 15 minutes, we (1) identified the workload selected by the individual; (2) computed the percentage of persons who successfully completed 15 minutes at their chosen workload; and (3) computed the average %VO2R and RPE of the final 10 minutes of the steady state session. To determine if the intensity of the selected workload was comparable between the peak test and simulated exercise session, paired *t* tests assessed differences in mean $\%VO_{2R}$ and RPE between the peak test and steady state session, while intraclass correlation coefficients ($\%VO_{2R}$) and Bland-Altman plots ($\%VO_{2R}$, RPE) assessed exercise intensity consistency between the peak test and simulated exercise session. Inspection of the simulated exercise data suggested that RPE increased over time, but $\%VO_{2R}$ did not. To further explore this observation, we completed 5 paired *t* tests for each variable comparing data from the 5th exercise minute to data obtained from the 7th, 9th, 11th, 13th, and 15th minutes. A Holm-modified Bonferroni correction was applied to control for Type I error. For all tests, significance was set a priori at $\alpha < 0.05$.

Results

The exercise intensity for each TT stage and perceived effort category is presented in **Figure 1A**. The exercise intensity of the first negative stage is vigorous and is shown in **Figure 1A** (75 ± 15 $\%VO_{2R}$). At light to moderate exercise intensities, RPE intensity categories did not accurately represent the true exercise intensity ($\%VO_{2R}$) (**Figure 1B**). During these intensities, participants perceived that they were working harder than was indicated by $\%VO_{2R}$. However, during vigorous and maximal intensities, perceived effort matched exercise intensity.

Simulated exercise session

When advised of the workload at which their first negative TT occurred, informed that this stage was thought to be moderate intensity, and instructed to select a workload that they could

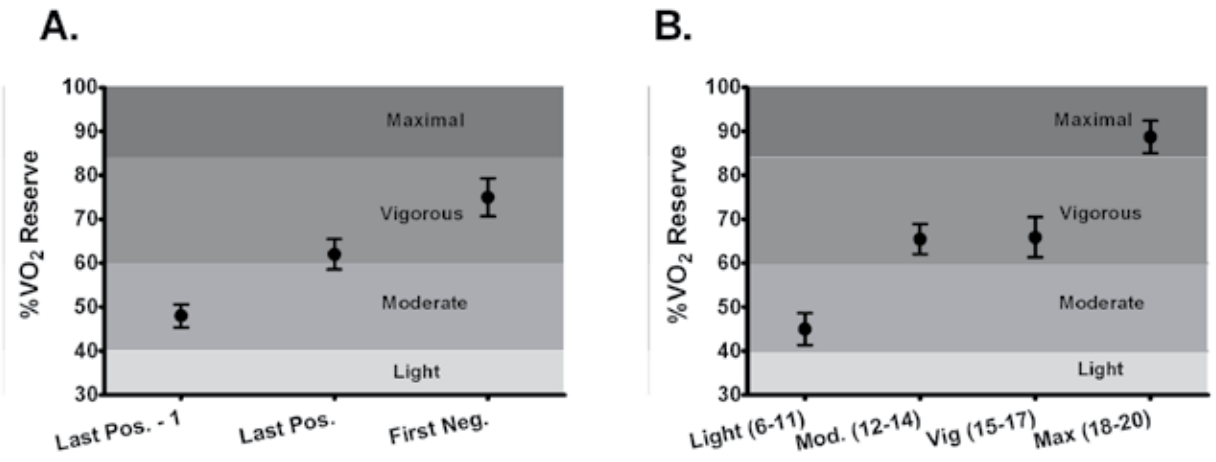

Figure 1. Actual intensity (mean±*SD*) of (A) the talk test stages and (B) rating of perceived exertion (RPE) categories during the incremental exercise test. VO_2 = oxygen uptake; Pos. = positive; Mod. = moderate.

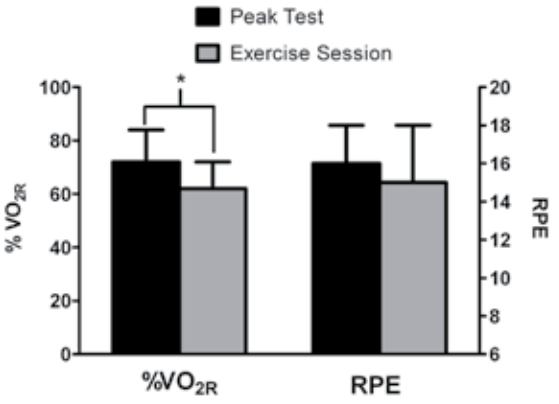

Figure 2. Actual (%VO_{2R}) and perceived intensity (RPE) of the workload selected for the simulated exercise session during the peak test and simulated exercise session. VO_{2R} = oxygen uptake reserve. *$P < .05$.

comfortably maintain for 15 minutes, most individuals (n = 8, 72%) selected the workload of their first negative TT. The balance (n = 4, 28%) selected one stage (+10 W) higher. All participants successfully completed 15 minutes at their self-selected workload. The average intensity and perceived effort of the selected workloads were vigorous and are presented in **Figure 2**.

Although the workloads were equivalent, intensity was greater during the peak test ($P = .04$). This difference is reflected by the intercorrelation coefficient (ICC = 0.168; 95% CI, -0.25-0.61), which indicates intensity was not consistent between the tests. However, the Bland-Altman plot (**Figure 3A**) suggests that consistency was adequate. Additionally, this plot suggests that the intensity difference and low ICC were driven by 3 outliers. While exercise intensity differed between the peak test and simulated exercise session, there was no difference in perceived effort between the tests ($P = .13$), and Bland-Altman plots suggest that perceived intensity was consistent between tests (**Figure 3B**).

Our secondary analysis of possible changes in exercise intensity during the steady state portion of the 15-minute exercise session suggests that

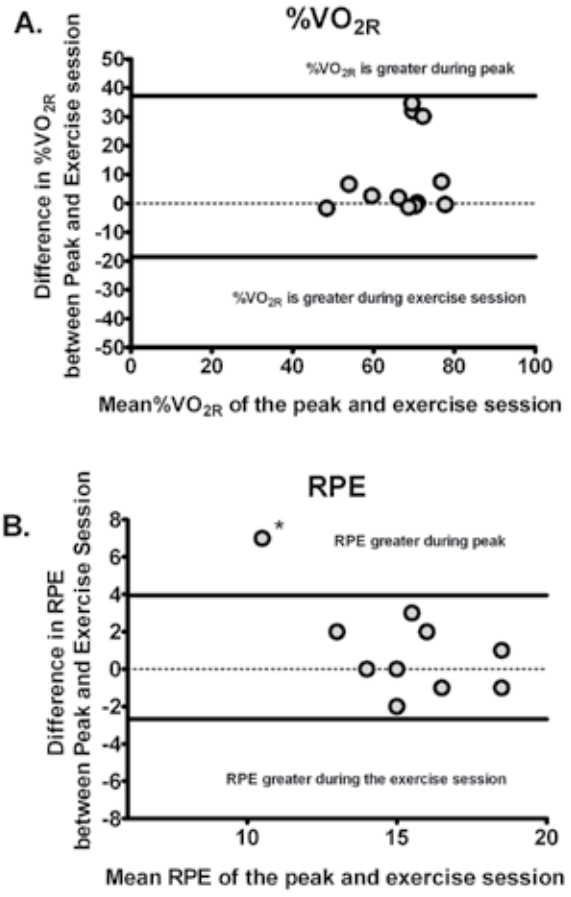

Figure 3. Bland Altman plots examining rating of perceived exertion (RPE) and percent oxygen uptake reserve (%VO_{2R}) agreement between the peak and exercise session. Peak refers to the incremental peak exercise test. Exercise session refers to the 15-minute fixed workload exercise session. Peak data are drawn from the workload self-selected by the participants for their exercise session. Exercise session data are averages of the final 10 minutes of the exercise session. *Excluded from the RPE 95% limits of agreement calculation because of an extreme mismatch between RPE and %VO_{2R}.

exercise intensity was constant between minutes 5 and 15 (**Figure 4A**). However, across this same time, there was a significant increase in perceived effort at minutes 9, 11, 13, and 15 when compared to minute 5 (**Figure 4B**).

Discussion

Our results suggest that if persons with paraplegia exercise at a workload that induces speaking discomfort, they are working at an intensity established as sufficient to improve fitness. The point at which our subjects first indicated speaking was no longer comfortable (ie, the first negative stage of the TT) had a mean intensity that is considered vigorous by American College of Sports Medicine (ACSM) standards.[13] Based on these results, participants could satisfy the US HHS minimum PA guidelines[1] by completing 75 minutes a week of arm crank exercise at a workload that made speaking uncomfortable. Conversely, if vigorous exercise is contraindicated, the TT could be used to cap exercise intensity (ie, persons could be counseled to select exercise intensities where speaking remained comfortable).

Our finding that persons with paraplegia can successfully use the TT to select a workload they can maintain for 15 minutes also indicates the TT could be used by the lay population to ensure their selected exercise intensity elicits a training effect. However, the selected workload was quite intense. Although all subjects completed 15 minutes, it could not be considered comfortable exercise. Fortunately, 10 minute bouts are sufficient duration for health benefits to be obtained.[1,13] Thus, an individual could meet the HHS guidelines by completing the following 3 days a week; exercising for 10 minutes, resting 10 minutes, then completing another 10-minute bout, with each exercise bout at an intensity sufficient to cause speaking discomfort. Nonetheless, given that speaking discomfort during exercise occurred at a vigorous intensity, this benchmark may not be an appropriate initial target when used by deconditioned persons. If moderate intensity exercise is the prescriptive goal, then the stage before the last positive stage (2 stages before the first negative) is an appropriate target (**Figure 1**). Given our testing paradigm, for any individual this workload would be 20 W lower than the first negative TT stage. Regrettably, we are unable to envision a simple process by which lay persons could use the TT to identify a workload that elicits a moderate intensity. At this juncture, feasible community TT applications appear limited to the first negative stage, that is, vigorous intensity.

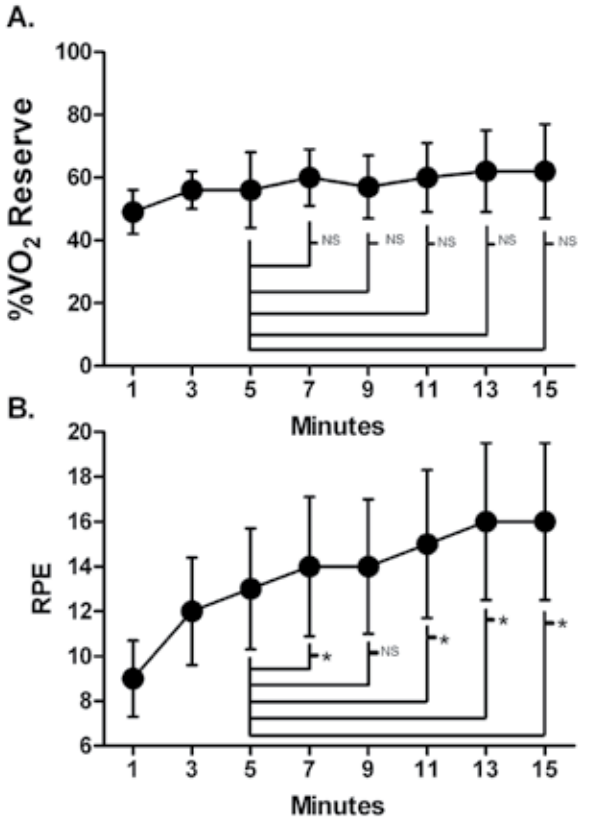

Figure 4. (A) Mean exercise intensity and (B) perceived effort during the 15-minute fixed workload. RPE = rating of perceived exertion; VO_2 = oxygen uptake. *Significant difference from minute 5 at $P < .01$ (Bonferroni adjusted); NS = non-significant ($P > .01$, Bonferroni adjusted).

Finally, our data suggest that perceived effort intensity (RPE) does not mirror exercise intensity at low intensities and during fixed workload sessions performed for longer than 5 minutes. This finding is in accordance with Lewis et al[4] who previously reported the absence of a relationship between RPE and both exercise heart rate and VO_2 in persons with paraplegia. Two results support our observation. First, at low and moderate exercise intensities of incremental peak test, we found that participants perceived that they were working more intensely than established by direct measurement. Second, data from the 15-minute exercise session show that at a high-intensity fixed

workload, the RPE increases during steady state exercise while the workload remains unchanged (**Figure 4**). This suggests our participants were using RPE as an index of peripheral effort rather than central effort. Goosey-Tolfrey and colleagues[5] recently demonstrated that highly fit person with SCI can successfully use RPE to regulate exercise intensity after an "anchoring" session. Collectively, we feel these data suggest caution in arbitrarily using RPE to select or regulate exercise intensity in persons with paraplegia. Instead, its use requires vigilant instruction and practice, which may limit its use in the community setting. Additionally, we caution researchers to be very clear when instructing their subjects on the use of RPE. Absent explicit direction and examples, persons with SCI may instinctively use RPE as a peripheral effort index.

Study considerations, limitations, and bias

Our testing was limited to persons with paraplegia; thus, we cannot be sure our observations can be extended to persons with tetraplegia. Given the hemodynamic instability inherent in cervical SCI, it is plausible that speaking discomfort during exercise could be driven by hypotensive responses rather than the VT. Additionally, while we have not tested whether these findings are influenced by fitness level or sports experience, our participants were of mixed fitness levels and sports participation backgrounds. Thus, we feel any potential bias is attenuated by sample variability. We have also based our projections of conditioning benefits at the target intensities on authoritative guidelines, not direct testing. Finally, these findings call for evaluation of the TT when using multiple exercise modes, especially handrim propulsion. Although handrim propulsion is implicated in the development of upper extremity pain and pathology in persons with SCI, it is also the most widely available of potential exercise modalities.

Conclusions

Persons with paraplegia are able to use the TT to select an arm crank exercise workload they can sustain for 15 minutes. The workload at which speech first becomes difficult (ie, the first negative stage of the TT) elicits a vigorous level of exercise intensity. As used in this protocol, RPE does not appear to be an accurate index of exercise intensity. It seems our sample used RPE as a peripheral, not central, intensity surrogate.

Acknowledgments

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